A Search for New Heroes

The Computer World Honors Program
2001 Case Study

The Next generation Payload Development Team (NPDT) -
Small Discovery Spacecraft

by

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Short Summary

The goal of your summary description is to briefly describe the benefit of your application and to differentiate your work from others in the Category. The best summaries communicate the benefit within a specific business or institutional context. These summaries will guide people to your case study for years to come. Please supply 40 words or fewer and write for a general audience, using simple, non-technical language. What is your project designed to do? How does it change and improve people's lives?

The use of high-end computer tools, concurrent design methodologies, and temporary team co-location from the early design phases has led to substantial quality improvements and time reductions, and increased the fun factor in the development of space based systems.

Long Summary

Describe your application and the information technology used in conjunction with it. Please keep your language simple and your explanations non-technical. Your project will be judged primarily for what it does and for its impact on people.

OVERVIEW

The Next Generation Payload Development Team (NPDT) at the Jet Propulsion Laboratory provides a customer with a state-of-the-art Concurrent Design and Analysis environment for the early Design stages that emphasizes a total Systems approach, and features Multi-Disciplinary temporarily co-located design teams, and interconnected, high-end Analysis and Design tools. These tools share and utilize a common 3D geometry of payload and spacecraft for their analyses and design. The NPDT provides support for payloads, probes, rovers, and dedicated SC studies and proposals, covering orbital and in-situ types of payloads for volcanic vents off the ocean floor, bore-holes in Antarctica, planetary surface and sub surfaces, Earth and planetary orbits, and atmospheric insertions. According to customers, the NPDT has managed to improve quality and shrink development time in the early design phases by factors between four and ten.

The concurrent analysis and design method developed and implemented in the NPDT environment can with slight modifications be applied for developing spacecraft, automobiles, oil & gas platforms, and other types of large and complex systems.

INTRODUCTION

Jet Propulsion Laboratory (JPL) managed for NASA by the California Institute of Technology is the lead U.S. center for robotic exploration of the solar system. Over the years JPL played central roles in the Viking, Voyager, Magellan, Galileo, Cassini, Deep Impact, Mars Global Surveyor, Mats Pathfinder (Sojourner) missions. As of year 2001 JPL spacecraft have visited all known planets except Pluto. Today the center is also actively involved in Earth Science missions. In addition to its work for NASA, JPL conducts tasks for a variety of other federal agencies.

Currently at JPL, large resources are put into efforts aimed at improving and changing the organization to effectively deal with developing smaller missions in the hundred million, rather than in the billion-dollar range. A large number of these missions are won based on competitive proposals in response to Announcement of Opportunities (AO's) from NASA headquarters. Writing and developing proposals is, therefore, becoming increasingly important for JPL.

In late 1996, it was decided that there was a need for a team that could provide early conceptual design analysis support for payload development and payload proposal work. This led to the development and implementation of the NPDT. Typically, payload or instrument proposals require high degrees of detail in their optical, radiometric, mechanical, thermal, and structural analyses. The NPDT is, therefore, utilizing what is considered high-end tools in its design and analysis work.

The NPDT can be modified both in terms of experts, and in terms of analysis and design tools. This makes it possible to provide development support for almost any type of space orbital and surface missions.

This summary starts with a description of the analysis and design methodology of the NPDT, continues with a brief discussion about its implementation, and ends with some examples of how this methodology has benefited projects supported by the NPDT.

THE ANALYSIS AND DESIGN METHODOLOGY

The analysis and design methodology utilized in the NPDT was developed and refined by the author in close cooperation with engineers and scientists over the last 3–3.5 years. The methodology is based on ideas from concurrent engineering, and from what the author in his earlier research has termed concurrent analysis and design.

The methodology is built up around eight central principles: (1) Analysis and design activities are performed by a multi-disciplinary design team; (2) the design team members work together in concurrent sessions; (3) "customers" and team members participate in the concurrent sessions; (4) analyses and design activities take place in a concurrent, and near real-time fashion; (5) inter-linked high-end computer tools are utilized in the concurrent sessions by the team members; (6) these high-end computer tools are used from the early parts of the design cycle; (7) common geometrical data (CAD) is shared electronically between the tools; and (8) CAD, structural, thermal, and optics data can be imported and exported to and from the design team.

Having multi-disciplinary design teams ensures that a total systems approach is taken, and that all relevant engineering and science areas are covered. Bringing the team members together in the same room for concurrent sessions makes it possible to deal with the relevant engineering and science disciplines concurrently. Another interesting thing happens when the customer takes parts in these sessions. Now, requirements, which the author prefers to call input parameters, can be challenged and changed in real time, a substantial time saving. As opposed to a meeting, real analysis and design work is performed during the concurrent sessions. Using accepted high-end tools for this analysis and design work ensures that the results generated have high enough fidelity to be used directly for making trade and design decisions. The tools to be used need to be verified and trusted by the experts in every field. Having these tools interconnected, and utilizing a common geometry for their analysis and design work has made the process so powerful and efficient that this work can be done in near real-time. This means that the tools can be utilized in the 3-3.5 hours concurrent sessions. Just 5 years ago, using high-end tools for such real-time work would have been impossible. Hardware and software limitations restricted the use of these tools to high-fidelity work on point designs in the later parts of the design cycle. Introducing these tools into the early conceptual design phases improves the design quality and makes it possible to come up with high-quality designs at a point in the design cycle where commonly only back of the envelope type of design quality was available. As a consequence, the number of expensive design errors discovered late in the design process can be dramatically reduced.

The use of high-end tools in the early design phases has another interesting side effect. The results, geometry (CAD) data, optics, data, thermal, and structural data can be ported to the next phases of the design cycle. There, they can be used as starting points for the refined design and analysis work required at those stages. Even more radical, since the design team is already using the same tools as are used in the later design phases, the concurrent design team might be able to support the design and analysis required also for the later parts of the design cycle. Consequently, one might be able to look at the design cycle as one process rather than a number of processes linked together. This could lead to substantial time and cost savings. The power of this approach was demonstrated for a sub-sea prototype that was brought from concept to machine shop ready engineering drawings in 3 weeks.

The utilization of a common geometry between the tools has also lead to large timesavings. For example, before, geometry was transferred manually from optics tools to mechanical tools, and from mechanical tools to the thermal, and structural tools. Each of these transfers would take some 3-5 days. Today, these transfers happen in minutes. This makes it possible to do a number of trades, analyses, and design modifications in near real-time using these tools. The last design principle emphasizes an open design and analysis environment. Being able to import and export geometry and analysis files of components, spacecrafts, launch fairings, rovers, and landers, saves time, and improves the design and analysis process in a number of ways: (1) The various components of a system can be represented more accurately. (2) Fit, orientation, fields of view, and interference issues can be dealt with more confidently. (3) Less time is spent redoing already existing, but external analyses and geometry data. NASTRAN decks would represent one such type of analysis data.

Finally, the NPDT utilizing this methodology has seen four-fold to ten-fold reductions in development time and costs.

THE NPDT IMPLEMENTATION

The NPDT is a multi-disciplinary, and standing design team, that provides support to proposals, studies, and to the development of prototypes. The initial version of the NPDT was set up to support optical instrument work. Later the NPDT has expanded its capabilities to effectively be able to support the development of space payloads, space and sub-sea probes, rovers, and dedicated spacecraft. The current set of high-end tools consequently, includes tools such as Code V™, ZeMax™, TracePro™, MODTool, Mechanical Desktop™ (MDT), Inventor™, Thermal Desktop ™ (TD), MSC Working Model 4D™, and MSC NASTRAN™ for Windows. Most of the NPDT tools are running on PC NT platforms.

The NPDT currently includes analysis and design experts in the areas of UV-V-IR optics, micro- and millimeter wave optics, mechanical, thermal, structural/dynamics, electronics/power, mechanical simulations, orbital analysis, radiometry, and costing. The NPDT environment and process is continuously being updated based on input from NPDT members and NPDT customers.

In its current configuration, the NPDT includes 9 stations, a mechanical/CAD/mechanical simulation station, a thermal station, a structures and dynamics station, an electronics station, an instrument station, a radiometry station, a cost station, an orbital analysis station, and a system station. To improve group interactions, any station's display can be shown on the large projection screen (s) in front of the NPDT room. Often this entails importing CAD files of spacecraft, landers, launch vehicles, and specific components, to use as starting points for a design. This brings higher degree of realism into the design, and cuts down on the development time. Most CAD files are imported as STEP files. In the case of optical instruments, the optics configuration and its rays are imported to MDT from ZeMax and TracePro on the optics station as SAT and IGES files. This data is used as a basis for designing, support structures and enclosures required for the optics. Electronics, telecommunication systems, antennas, booms, radiators, etc., are also added to the design at this station. Dimensions, and masses of these components are based on NPDT analyses. From the developed design, preliminary mass, volume, and area estimates can be estimated. For mechanical design work MDT and Inventor™ are being used. At this station, true physical simulations of landers descent, rovers' mobility and stability, and strength of mechanisms to mention a few are also being performed. MSC Working Model 4D™ is used for this work.

SAMPLE PROJECTS SUPPORTED

Over the last 3 years, the NPDT has provided a wide range of support to a number of different types of studies and proposals. Most of these support efforts included 2-3 concurrent sessions, plus some off-line work in between them.

The team supported a design study of a 150 km fuel cell rover. For this study, the team designed, together with rover experts, the complete rover. The design started with defining the electronic box based on the electronics required for running the rover and its instruments. The frame and wheels were then added to fit with the electronics box. Inflatable wheels were used for this design. The electronics box and its internal components were made parametric, enabling quick trade studies of different configurations with solar panels and fuel cells for different roving distances. A structural analysis was run on the frame geometry to confirm structural integrity during launch, landing, and roving operations. Next step was to see whether the rover would fit in the specified lander. For this, a lander model was imported as STEP file, and the rover was made to fit on it. With tires inflated, this became impossible, forcing the team to address packaging and deployment issues such as inflation sequence of tires and the need for actuators. All this was done using the NPDT mechanical tool. The rover was successfully fit onto the lander. Finally, rover deployment and roving was simulated through the porting of the rover geometry to the mechanical simulation tool. This simulation added insight into the stability of the rover during lander exit, and during surface operations. This showed that the high center of gravity made the rover somewhat unstable, especially during lander exits. However, during roving on the defined terrain stability seemed acceptable. The simulation also confirmed that the power provided for each wheel, given mass and friction coefficients, was sufficient to move the rover around on the surface, and over and between obstacles. A mass list was also provided.

The team provided support for a number of payload proposals for the Europa orbiter. To make sure that there was a clear understanding about how the payload was to be integrated onto the spacecraft, a STEP file of the orbiter correctly dimensioned was imported into the NPDT environment. This gave a clear understanding of available space on the orbiter, and potential FOV conflicts for instruments and radiators. For calculating sun exposure, Jupiter, and Europa exposure, the geometry of the orbiter and the attached payload were ported to the orbital analysis tool. Based on the analysis there, it was determined which sides were less exposed to the sun, and Jupiter. These sides were then used for placing radiators and low temperature detectors. For sizing radiators, a thermal analysis was performed based on the defined orbit, the orbiter, and payload geometries, the defined component temperatures, and the power dissipation from the electronics components. Optical geometries were developed on the optics tool, and packaging based on structural and thermal analysis results was put together on the mechanical station. The packaging starting point was the electronically transferred optics tool configuration. The structural analysis included launch load analyses of mechanisms, and supporting structures. Electronic block diagrams, mass, power, data rate, data storage, and cost data were also provided.

The NPDT also supported the development of a deep-sea thermal vent optical probe prototype. The probe was designed to be inserted into thermal vents on the ocean floor—down to 8 km—and to look for life forms at temperatures above 570K. The probe included visual wavelength cameras, UV spectrometers, and lasers. The team developed front-end and back-end optics, and provided support in packaging the electronic components, cables, lasers and fiber optics. The main packaging problem was providing easy access to optics and electronics in a very small space. For this design effort, structural analyses were performed on the main housing and the thinner front cylinder of the probe. The geometry developed on the mechanical station was used as basis for these analyses. The turn-around time for this support effort was quite exceptional. Within a week, structural analyses; design of the optics, the probe, cable, and fiber-optic feed-throughs; and packaging had been completed. And, within 3 weeks, machine shop-ready engineering drawing had been delivered from the NPDT. This shows that effectively utilizing interconnected high-end tools from the early parts of the design process makes it possible to dramatically compress the design cycle, and bring a design to engineering drawing level in a very short time. The next step would be to test this approach for larger projects, and eventually for flight projects. The probe was successfully taken down to 1.6 km ocean depth.

CONCLUSIONS

Team members and customers are starting to see substantial quality improvements, and time and cost savings through the utilization of the design approach discussed in this summary. They also strongly emphasize that they find the concurrent design environment of the NPDT more productive and fun to work in than the traditional office – meeting environments.

The aim of the author is to bring the power of this design approach to the later parts of the design process, and test it for a larger prototype, and then for flight hardware. The author expects "unheard of" cost and time savings, similar to those achieved for the Loihi probe. Through these experiments, the author hopes to encourage his readers to look at the design process as a continuous process, rather than as a sequence of phases with high walls between them. First, when that is achieved will projects be able to reap the real benefits of this design approach.

It is the hope of the author that the utilization of this methodology eventually will spread beyond the space industry, for example, to the automobile industry, helping them cut costs, improve quality, and reduce time to market, and ultimately help make these industries more competitive.

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Benefits

Has your project helped those it was designed to help? In your opinion, how has it affected them? What new advantage or opportunity does your project provide to people? Has your project fundamentally changed how tasks are performed? In your opinion, have you developed a technology that may lead to new ways of communicating or processing information? How might that change unfold?

The NPDT development was initiated some 5 year ago to help JPL proposal managers develop technically superior optical payload proposals. Later the team developed analysis and design capabilities to also support the development of other payloads, complex integrated payloads, rovers, and sub-sea probes. At the same time the NPDT also demonstrated that it could support design projects beyond just the proposal stage. In one case, for a sub-sea probe prototype, the team demonstrated that it could bring a design from concept to engineering drawings in a very short time. In that case, only 3 weeks. In the fall of 1999, the prototype was successfully taken down to 1.6 km and inserted into a thermal vent.

The NPDT has enabled proposal managers to generate proposals that are technically better, in a shorter time, and at a lower cost than before. The team has also dramatically cut costs—usually down to one-quarter and sometimes one-tenth of the previous cost—for JPL, which funds most of the proposals, studies, and projects that the NPDT supports.

These quality and productivity gains have become possible through the utilization of the NPDT based analysis and design methodology. The methodology represents nothing short of a paradigm shift in the way complex technical systems are developed. A central part of the methodology is to bring experts together for 3-4 hour concurrent sessions in a room where they all they have access to high-end computer hardware and the relevant analysis and design tools. These tools include CAD, structural, thermal, and simulation packages. The computers are connected together enabling a smooth exchange of digital data and 3D geometries. The resulting environment makes it possible for the team members to do analysis and design, to communicate with the other discipline experts, to solve problems, to do trades, and to make design decisions, all in a real time fashion. Some work will, of course, still be done off-line. This approach, therefore, represents a dramatic departure from the model where the experts work alone in offices and share their findings in progress meetings. Such meetings have traditionally been used for information exchange only.

By having all the NPDT members and the customer (proposal, study, or project manager) in the same room at the same time, improves the interactions between the various subsystem experts, makes it possible to solve interface issues in real time, gives the team members a chance to see and appreciate all the parts of a system as opposed to just their own subsystem, encourages cross-disciplinary problem solving, and improves communication between the team and its customer. These benefits also make a concurrent design team the perfect place for an organization to train its younger staff.

Bringing team members from an office environment to a concurrent design environment, do represent significant changes to the way they work. In the concurrent design and analysis environment, they will need to be able to listen, and work at the same time, perform analysis and design in real time, be able to respond quickly to requests from the other experts, and enjoy working in a team. Most team members fit well into the concurrent design and paradigm and end up enjoying it tremendously. However, to make the transition smooth, training is required.

On a smaller scale, the NPDT customers also need to adjust to working under the concurrent design and analysis paradigm. For example, they need to bring the information that they have available about their science goals, payloads and mission to the NPDT even before the first session. Part of the NPDT design and analysis paradigm is the use of high-end analysis and design tools from the early design stages. This leads the NPDT to request that customers also provide if available digital 3D CAD models as opposed to pictures of spacecraft, landers, rovers, parts, and launch farings. In many cases, such data is difficult to get hold of, simply because the relevant parties are not used to getting these types of requests. Here, however, things are changing for the better, but change is slow.

The Importance of Information Technology

Why was information technology particularly important to this project? How did information technology contribute to this project? Describe any new technologies used and/or cite innovative uses of existing technology. For example, did you find new ways to use existing technology to create new benefits for society? Or, did you define a problem and develop new technology to solve it How quickly has your targeted audience of users embraced your innovation? Or, how rapidly do you predict they will? Does your work define new challenges for society? If so, please describe what you believe they may be.

Process, people, and tools constitute the three main elements of the NPDT based design and analysis methodology. The process and people elements were discussed under the "LONG SUMMARY" and the "BENEFITS" sections respectively. In this section, the focus will be on the tools or the information technology.

The NPDT has been built up to effectively utilize high-end analysis and design tools from the early design phases for doing trades and making design decisions. Utilizing these high-end tools in a real-time setting would just 7 years ago have been quite impossible. Neither computer hardware nor software would have been available. Today, however, high-end software developers have started developing standards making the sharing of geometries and data between their software packages easier. At the same time, most of the high-end tools have gone from command line interaction to a graphical user interface making them easier to learn and faster to operate. Parallel to this computer hardware has come to a point where a number of computer intensive tasks can be performed in near real-time. In some cases, where powerful NT systems can not perform the required calculations, the NPDT utilizes supercomputers.

High-end tools and powerful computers have also made it possible to develop mature design concepts in a short time. The NPDT utilizes the same high-end tools in the early design phases as are being used in the later design phases. This makes it possible to transfer CAD geometries, structural, thermal, and true physics simulation results to the next design phases directly. Traditionally, the work done in the early design phases in spreadsheets and on the "back of an envelope" would be ignored by the experts in the next design phase. These were the experts that would bring a study or proposal to actual hardware. Consequently, one should expect significant timesavings by utilizing the NPDT approach. Such time savings were already demonstrated when the NPDT took a sub-sea probe prototype from concept to engineering drawings in just 3 weeks. Without the high-end tools, such a feat would have been impossible. However, this is the way of the future. By utilizing concurrent design teams and high-end tools from the early design phases, it becomes possible to create effective designs quickly, reduce the number of later design errors, and utilize the same the same data and geometry concept to finished hardware. As a result, the many design phases in a space mission might be eliminated and the design process can be speeded up dramatically. Again the sub-sea probe illustrates this point. Consequently, more space missions that will increase the general population's knowledge about space can be executed for less of taxpayers' money. On a larger scale, the utilization of the NPDT based methodology can speed up the time to market, improve quality, and applied to commercial companies increase their competitive edge. This could be of special interest to the US aerospace industry that is now facing tough competition from overseas.

The NPDT is a methodology that was developed to solve a new problem by utilizing current hardware and software. However, the methodology might in itself be regarded as a technology, if that is the case, a new technology was developed by tweaking existing technology to solve a new problem. The new problem being bringing a concept to hardware at less cost, shorter time, and with higher quality. That is what the NPDT based methodology developed into. So far, it has been applied to space related proposals, studies, and projects.

The NPDT has developed a strong customer base. Both customers, line managers, team members are today strong supporters. The team members were great supporters from the beginning, customers started coming on-board after a year, and the organization started putting weight behind the team after three years. Now, after five years, it seems that the team is becoming a required part of the proposal and study process at JPL.

However, there is still work to be done before the institution is ready embrace the methodology for developing hardware. A time perspective of some 2 years is probably realistic here.

Concurrent design teams perform at their best when the members enjoy working in a team environment, are cross-disciplined, have hardware, manufacturing, and testing expertise, and know how to use various high-end computer tools. This poses a challenge to the way engineers are currently educated. The engineering schools should be encouraged to develop cross-disciplinary curricula and to set up concurrent design team environments that the students could use for developing their cross-disciplinary designs. The NPDT has already taken the first step on this path. Last summer the team let a group of JPL summer students utilize the NPDT environment for developing a Mars mission concept. In 5-7 years, concurrent design teams are likely to become the standard way of working in a number of space, aerospace, and automobile, and other engineering and technology corporations. Software and hardware performance will play central roles in this development.

Originality

What are the exceptional aspects of your project? Is it original? How? Is it the first, the only, the best or the most effective application of its kind? How did your project evolve? What is its background?

High-end computer tools and hardware is available to anyone. What is new about the NPDT is that a methodology, process, and environment was successfully developed and implemented for utilizing these capabilities in the design process to bring a design from concept to hardware in a short time. There are teams working in a concurrent fashion at the Aerospace Corp, TRW, at the European Space Agency's Technology Center (ESTEC) in the Netherlands, at Astrium in Germany, and at the University of Munich to develop preliminary designs. There is also a second team design team at JPL called Team X. Some of these teams are moving in the direction of the NPDT, but they are behind, and most of them are built up around spreadsheet environments. That the NPDT is ahead was clearly shown at the European Systems Engineering Conference in Munich, September 2000 where representatives from all teams were present for discussions. Currently interest for the NPDT based methodology is coming from The National Aeronautics and Space Administration (NASA) headquarters, various NASA centers, the Japanese Space Agency (NASDA), commercial US aerospace companies, automobile companies, and oil and gas exploration and production companies.

Before the author joined JPL he developed in his dissertation research a new design methodology for developing spacecraft and payloads. A number of concepts and ideas from this research were later implemented in the NPDT based methodology and environment. As such, the methodology has a strong academic foundation. The NPDT started as an approach for providing JPL with higher quality proposals for optical instruments. To do this, required the use of high-end tools very early on in the design process. As the design process evolved and the team started supporting other types of payloads, rovers, sub-sea probes, and dedicated space craft, it became clear that the use of high-end analysis and design tools clearly benefited also these projects.

It is, therefore, fair to say that customer needs and NPDT-members input, together with the author's research and visions that created the NPDT based concurrent design and analysis methodology.

Currently, the author is training experts at NASA Marshall Space Flight Center to utilize the NPDT based design and analysis methodology. There, the people, and tools are different, but the general methodology is the same.

Success

Has your project achieved or exceeded its goals? Is it fully operational? How many people benefit from it? If possible, include an example of how the project has benefited a specific individual, enterprise or organization. Please include personal quotes from individuals who have directly benefited from your work. Describe future plans for the project.

The NPDT has since its start supported about 70 different proposals and studies. Only last Fiscal Year it supported 30 customers, an increase of 100% from the previous year. The NPDT has built up analysis, design, and simulation capabilities for supporting the development of optical payloads, rovers, dedicated spacecraft, complex mechanical booms, mechanisms, and spinning antennas. At the same time, the NPDT based methodology has made it possible to bring a concept from its initial stages to engineering drawings in very short time. The initial goal was simply to develop capabilities for supporting the instrument proposal process. These have been exceeded by orders of magnitude.

The NPDT provides today full support to its customers and is as such fully operational, however, at the same time it is in constant development, based on changing customer needs. That is the nature of concurrent design teams utilizing high-end tools, they will always be in development. New software, or new computer hardware may provide opportunities for doing new types of analyses and design activities. For example, over the last two years, powerful true physics simulators with interfaces to many CAD programs and structural analysis packages have come available for NT computers. This made it possible to simulate how well different rover concept would be able to deal with the Martian terrain. The same simulators could be used for improving the design of spinning antennas, and surface landers.

Assuming that 7 people on average per proposal or study benefited directly from the NPDT support, then over the last 5 years about 500 people in total have benefited. Add to that JPL managers, students, and the team members, and the number easily adds up to 700 hundred. The NPDT provided very important support for a sub-sea probe project. The details of the project ~~are given~~ in the "LONG SUMMARY." The customer here claimed that without the NPDT exceptional turn-around he would simply not have been able to develop his probe in the time he had available. NPDT customers have been very happy and most of them come back. Some of their sentiments are reflected in the following comments from two independent customer surveys: "Added significant value to instruments," "Would love working with them again," "We were really impressed with the technical design," "Amazing efficiency in getting a viable design completed in a surprisingly short time," "It was money well spent," Partners were extremely impressed with concurrent engineering (ce) abilities and remote access capabilities," and "The team effectively interfaced with partners (industrial and academic)."

The NPDT aims at adding in new optical analysis and design capabilities, move the NPDT concept into the later design phases, and eventually demonstrate that the NPDT based methodology can be used for developing flight hardware. There are also plans for utilizing supercomputers for improving and speeding up the structural, thermal, and possibly the computational fluids dynamics (CFD) analyses tasks. Plans are in place for providing training and advice for setting up concurrent design teams at centers throughout the NASA system.

Difficulty

What were the most important obstacles that had to be overcome in order for your work to be successful? Technical problems? Resources? Expertise? Organizational problems? Often the most innovative projects encounter the greatest resistance when they are originally proposed. If you had to fight for approval and/or funding, it would be useful to include a summary of the objections you faced and how you overcame them.

The development of the integrated NPDT environment meant that a number of file transfers between commercial off-the-shelf (COTS) tools had to be dealt with. For example, geometry and data files had to be transferred from the optics tools, Code V and ZeMax via TracePro to Mechanical Desktop (MDT); from MDT to Thermal Desktop; from MDT to NASTRAN, from MDT to Working Model 4D (now visualNASTRAN); from MDT to the team's Space Analysis Program (SOAP); from ZeMax to MODTool (JPL developed); from NASTRAN to ZeMax; and from NASTRAN to MODTool. In general, file transfers of data and geometry between tools using the same file format worked in fine. However, such interfaces still would be less than perfect. The NPDT dealt with these problems in three ways. Process problems, such as making sure that the same coordinate system appeared in both applications, or that all rays or parts were transferred from one tool to the next were dealt with through checking manuals, and trial and error testing of different cases. More serious file transfer problems were brought to the attention of the developers, who in general responded favorably to the NPDT requests. With a number of these developers, the team has developed very useful and productive relationships. In other cases, such for the interface between MODTool and ZeMax the NPDT developed its own file transfer scheme.

Setting up design teams such as the NPDT does require investment up-front in facilities, computers, overhead screens, video switches, and video conferencing, as well operational budgets for developing new customer demanded analysis and design capabilities, upgrade hardware and software, and for training. These items add up to a high dollar value. For an organization with a high number of programs competing for a small pot of infrastructure money, serious funding for these types of design teams are difficult to get. This has been the case at JPL. Funding for similar design teams at commercial corporations should be easier as cost and timesavings, and quality improvements are reflected directly in their accounts.

Standing concurrent design teams set to support a high number of customers are only as good as the people on the team. It is, therefore, crucial that such teams are staffed with some of the organization's best. Providing the right incentives, therefore, becomes crucial. Such incentives, can range from giving the members access to powerful computer hardware and software (a natural), have them be part of developing new analysis and design capabilities, provide them with plenty of time to get sharp in their fields and on their tools, and have them work on the design team at least 50% of their time. If such elements are not in place, these concurrent design teams will suffer. The NPDT is currently going through such a period. But things are about to change.

The best way to get started with setting up a concurrent design team is to get some customers who are willing to utilize the team as it is being developed for free or for a subsidized rate, and then work closely with them to define a concurrent design team that fills their needs. Then from there, the goal would be to generate a constant flow of satisfied customers. Knocking on doors in the organization, writing papers and gather external support are ways of getting the attention of the organization. This was the path that was taken by the NPDT. However, without strong high-level management support these teams will not survive. Any concurrent design team needs to be institutionalized to prosper.

The optimal situation would, of course, be to get a high-level manager to put the required money up-front and commit for annual operations and development costs. Such a commitment would probably only come after a successful completion of concurrent design pilot project. Taking this approach would make it possible to reap the rewards of these concurrent design teams in months rather than years.